ISSN (Online) 2395-2717

International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)

Vol 4, Issue 3, March 2018

Review of TSR as a SVC for Reactive Power Compensation in Transmission Line

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Abstract: **-- This paper presents, modelling and simulation of Thyristor Switched Reactor (TSR)-Based Static VAR Compensator (SVC), which is one of Flexible AC Transmission Systems (FACTS) controllers. The results show that significant improvement on reactive power compensation and bus voltage regulation could be achieved by using the TSR-based SVC. A SVC performs such system improvements and benefits by controlling shunt reactive power sources, both capacitive and inductive, with high tech power electronic switching devices.**

Keywords:—**Static VAR Compensator (SVC) ; Thyristor switched reactor (TSR); modelling of TSR**

I. INTRODUCTION

The Static VAR Compensator (SVC) is today considered a very mature technology. It has been used for reactive power compensation since the 1970s . There are multiple applications within power systems, e.g. to increase power transfers across limited interfaces, to dampen power oscillations and to improve the voltage stability margins.[3] VAR compensation is defined as the management of reactive power to improve the performance of AC power systems. The concept of VAR compensation embraces an extensive and diversified field of both system and customer problems, especially related with power quality issues, since most of power quality problems can be minimized or solved with a sufficient control of reactive power. Generally, the problem of reactive power compensation is observed from two aspects, load compensation and voltage support. In the loading point of view, compensation the objectives are to increase the value of the system power factor, to balance the real power drawn from the AC supply, compensate voltage regulation and to eliminate harmonics produced by fluctuating non-linear industrial loads. The voltage support is generally required to reduce voltage fluctuation at a given terminal of a transmission line.[1]

The SVC is both reactive power generator and reactive power absorber. The basic structures of a Static VAR Compensator (SVC) are fixed shunt capacitor (FC) and Thyristor Controlled Reactor (TCR) [2]. The most severe power quality problems are voltage sags and interruption, harmonics and flickers and low power factor. Failures due to such disturbances cause a huge impact on production cost. Especially, modern industrial equipment is more susceptible to power quality problems. Power quality problems as follows: computers or other electronics damage, lights dim and flickers, loss of synchronization of processing equipment, motors or other process equipment malfunctions, transformers and cables overheating, problems with power factor correction equipment, noise interference to telecommunication lines and many more.[8] Typical applications of SVC are: maintain constant voltage within a specified level, improve power factor, correct phase unbalance, dynamic stability improvement and improve power system steady state[5].

II. STATIC VAR COMPENSATOR (SVC)

The Static VAR Compensator (SVC) is today considered a very mature technology. It has been used for reactive power compensation since the 1970's. The many applications within power systems, like to increase power transfers across limited interfaces, to dampen power oscillations and to improve the voltage stability in transmission network. An SVC is a shunt connected device across the transmission line whose output adjusted to exchange either capacitive or inductive currents to the connected system. This current can be controlled to regulate particular parameters of the electrical power system (typically voltage of bus). The thyristor is an integral part of the SVC and to enable control of its reactive power flow in the line. An elementary single phase thyristor controlled reactor consists of a fixed (usually air core) reactor of inductance L and a two anti parallel SCRs. The device means SVC gets into conduction by simultaneous apply of gate pulses to SCRs of the same polarity. In addition, it will automatically turned off thyristors immediately after the ac current crosses zero, until the gate pulse is reapplied. The current flows in the reactor can be controlled from maximum to zero by varying the firing delay angle. In this way the SCR conduction delayed with respect to the maximum value of the applied voltage in each half-cycle and thus the time for which the current conduction interval is controlled.[6]

The structure of a SVC is shown in Fig.1, which XL represents the series inductor. The SVC uses number of thyristors to rapidly add or remove shunt connected reactors. The resistance of the transmission network is neglected. By controlling the firing angle (α), it is possible to control the current through the inductor. The TSR branch is switching controlled by set firing delay angle to thyristor in order to obtain a variation of the net SVC inductive reactive current. [5]

The static VAR compensators' (SVC) use combinations of shunt reactor and shunt capacitor with thyristors of high voltage and current rating for obtaining fast and accurate control of reactive power flow. The static VAR compensation (SVC) is also known as static VAR system(SVS) [1]. A static VAR generator may be of a controlled reactive impedance type, employing thyristor-controlled and switched reactors and capacitors, or synchronous voltage source type, employing a switching power converter, or a hybrid type, which employs a combination of these elements. Although the operating principles of these VAR generators are disparate and their V-I and loss versus VAR output characteristics, as well as their speed of response and attainable frequency bandwidth, are quite different, they all can provide the controllable reactive shunt compensation [7].

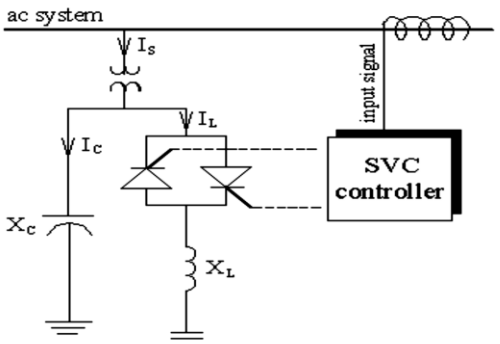

Fig.1 Single diagram of a typical SVC

The main feature of SVCs over simple mechanically switched compensation schemes is their near instantaneous response to change in the system voltage. For this reason they are often operated at close to their zero-point in order to maximize the reactive power correction. They are in generally economic, high capacity, fast, and more reliable than dynamic compensation schemes[3].

Advantages of SVC are as follows
1) Improved system steady-state stability.
2) Improved system transient stability.
3) Better load division on parallel circuits.
4) Reduced voltage drops in load areas during severe disturbances.
5) Reduced transmission losses.
6) Better adjustment of line loadings.[3]

Thyristor Switched Reactor (TSR)

Fig-2, shows the scheme of a static compensator of the Thyristor Switched Reactor (TSR) type. Each of the three phase branches includes an inductor (L), and the thyristor switches T1 and T2. Reactors can be both switched and phase-angle controlled[1]. By enforcing partial conduction of the thyristor valve, the effective reactance of the inductor may be varied in a continuous manner. This is achieved by controlling the firing angle of the thyristor valve, thus controlling the TSR susceptance and its ability to absorb reactive power. [3]

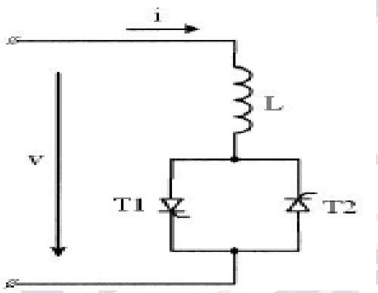

Fig.2 Thyristor Switched Reactor.

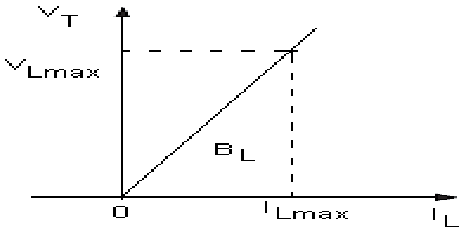

Fig.3 Operating V-I area of TSR

VLmax = Voltage limit
ILmax = Current limit
BL = Succeptance of reactor

Fig.3 represents operating V-I characteristics of TSR

The TSRs have following properties: its operating principle simple, delay of one half a cycle and no generation of harmonics. Filters are traditionally used to absorb harmonic generated by the SVC structure and large industrial loads. In order to obtain harmonic generation TSR is used instead of a TCR. Also, with choice of TSR both voltage stability and stepwise control of bus voltage have been provided. Actually, the configuration of both TSR and TCR are same the difference being TSR is switched reactor and TCR is controlled reactor, where firing angle is controlled.[1] Partial conduction is obtained with gating angles between 90° and

180°. By increasing the thyristor gating angle, the fundamental component of the current reactor is reduced

IV. MODELLING OF TSR

In modelling of TSR SVC Controller plays a very important role for the operation TSR when the reactive power compensation requires. SVC control system consist of main four modules in modelling of SVC control system.

i. Measurement system measures the positive sequence primary voltage.
ii. Voltage Regulator uses a PI regulator to regulate primary voltage at the reference voltage (1.0 pu specified in the SVC Controller).
iii. Distribution unit uses the primary susceptance Bsvc by the voltage regulator to determine status of turn ON/OFF of the TSR.
iv. Firing Unit consists of three independent subsystems, one for each phase (AB, BC and CA). Each subsystem consists of a PLL synchronized on line-to-line secondary voltage and a pulse generator for each of the TCR and TSC branches.[2]

A few assumptions have made that should be kept in mind when considering the models presentation. These assumptions are as follows:

i. The devices are considered lossless.
ii. Harmonics are being neglected, only the fundamental component is considered.
iii. Balanced operation is assumed, i.e. only the positive sequence component is considered.[3]

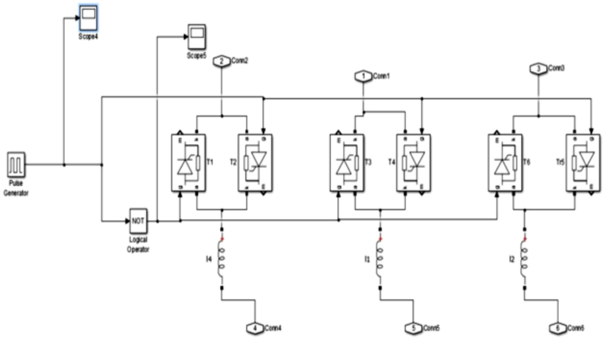

Fig.4 Modelling of TSR

Fig.4 represents modelling of TSR. Three units of single phase TSR are connected in delta connection. In each unit of TSR two Thyristors are connected in anti parallel connection in series of inductor. Thyristors are fired by giving Pulse to the each gate terminal of the SCR. It is in parallel connected to the load bus or transmission line. A six-pulse generator has been used to fire six thyristors of the TSR.

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